Overview of Advanced Surface Science activities at CERN

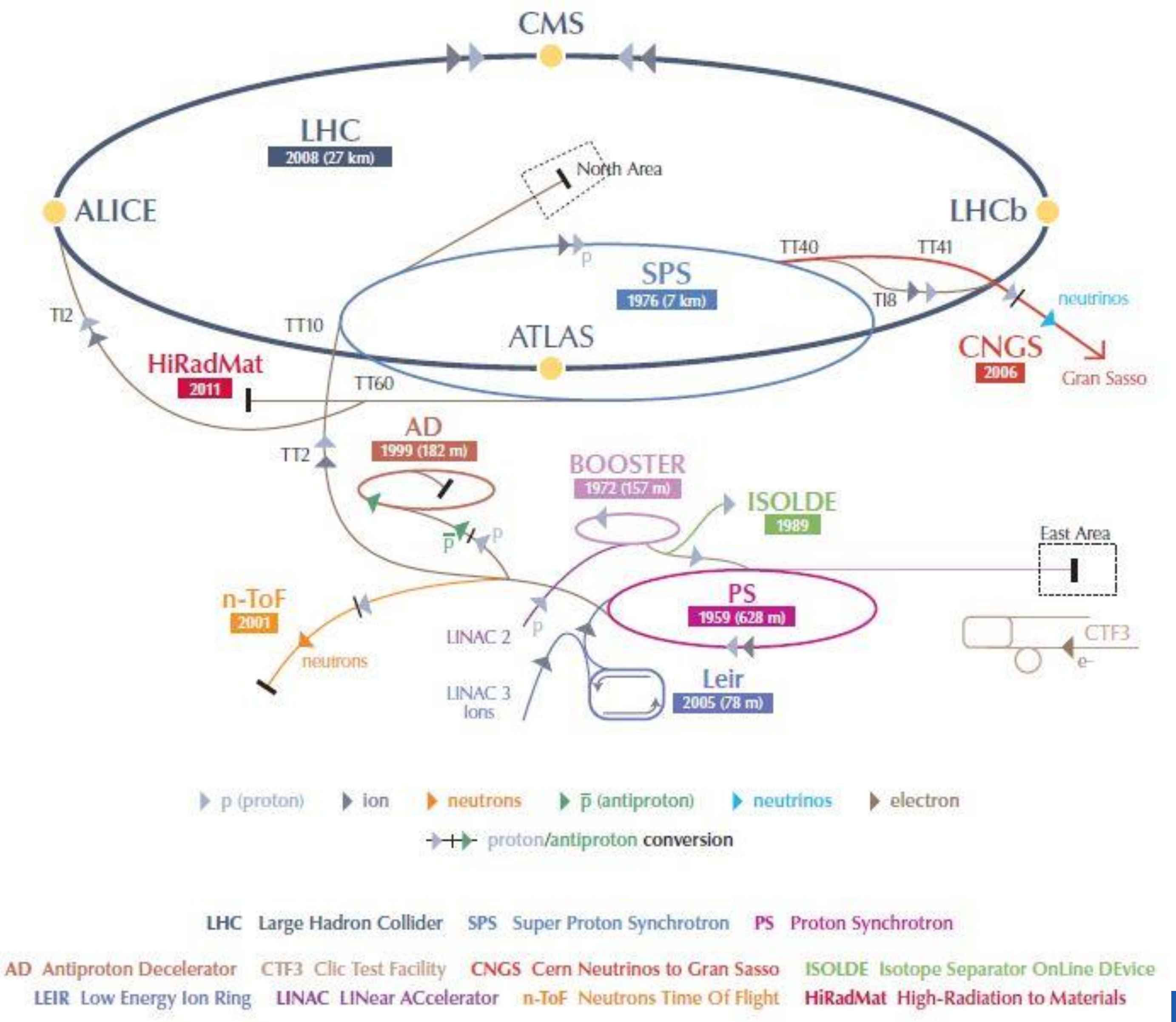
www.cern.ch

S.Calatroni, M.Taborelli
TE-VSC-SCC

CERN (European Organization for Nuclear Research)

20 member states + associates (Romania, Israel, Serbia…) + observers (USA, Russian Federation, Japan….)
Some 2500 staff members and 8000 visitors

Cern accelerator complex



The LHC , Large Hadron Collider

Size

27 km circumference, in a tunnel underground (100-150 m)

Collider (present parametrs)

Proton-proton (ion – ion) collisions at 4 TeV + 4 TeV for protons (world's highest energy), 2 beams made of about 2000 bunches of 10^{11} protons spaced by 50 ns, 11KHz revolution frequency, 10h beam lifetime

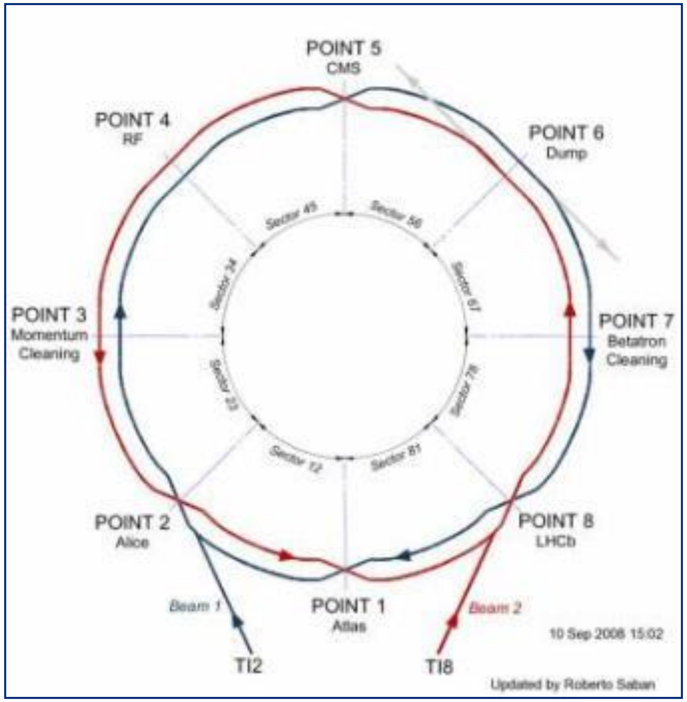
Four main experiments and detectors

About 20 collisions per bunch crossing or $6*10^8$ collisions/s

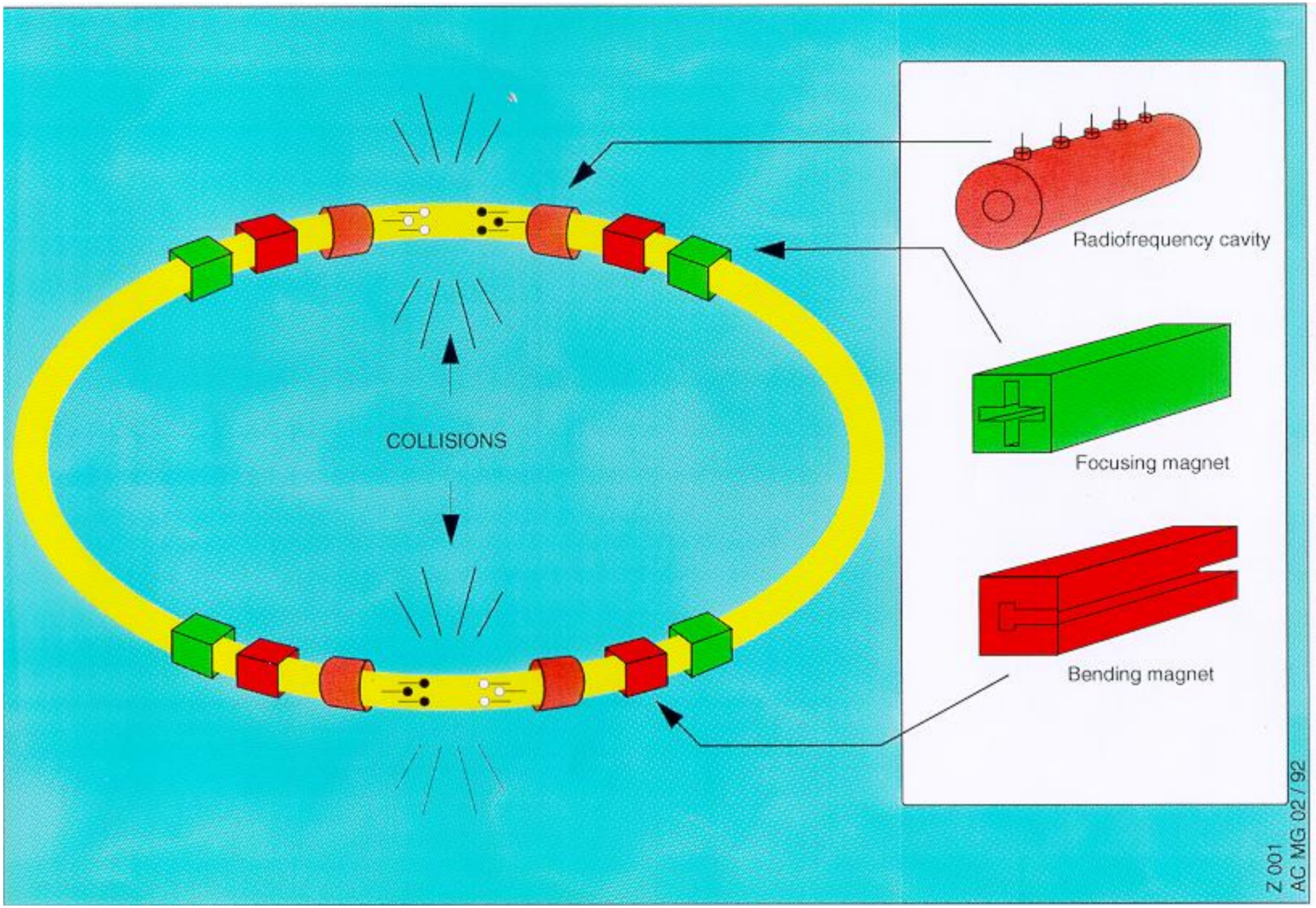
15 Petabytes data/year

LS1 upgrade

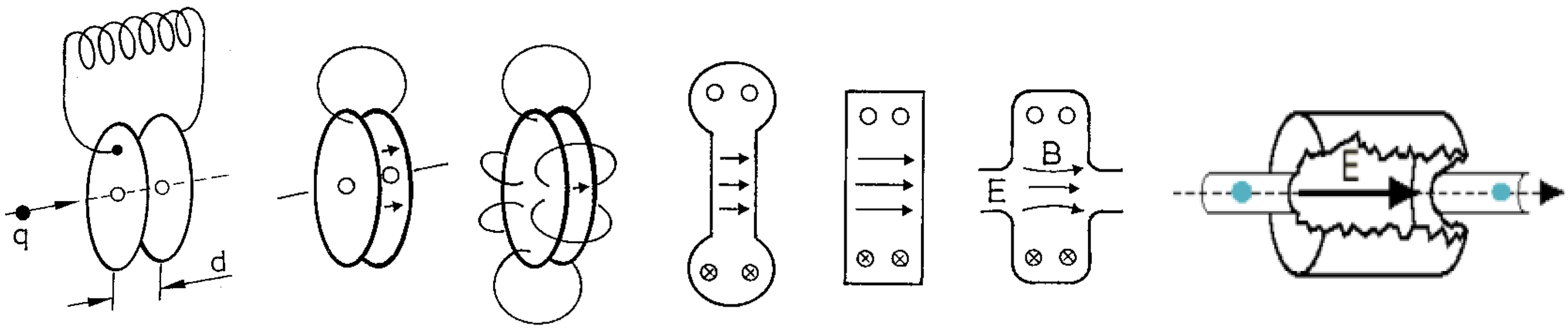
A large upgrade program is under way in order to attain 7 TeV + 7 TeV proton collisions, higher availability of the machine

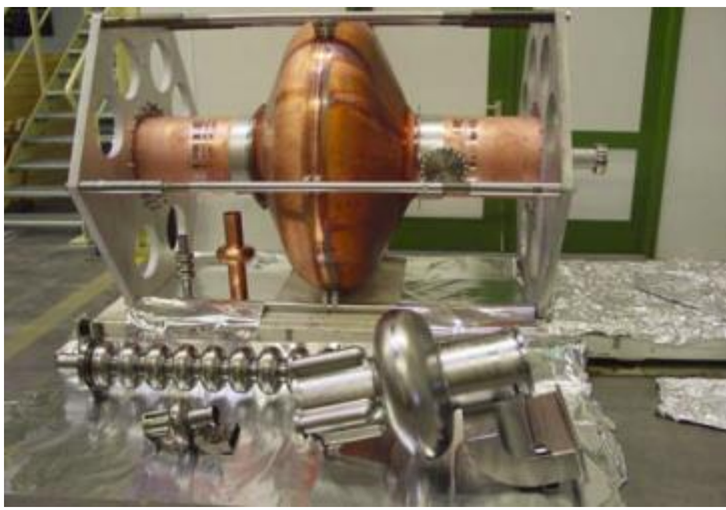


Basic components of particle accelerators

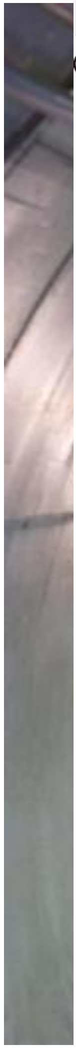


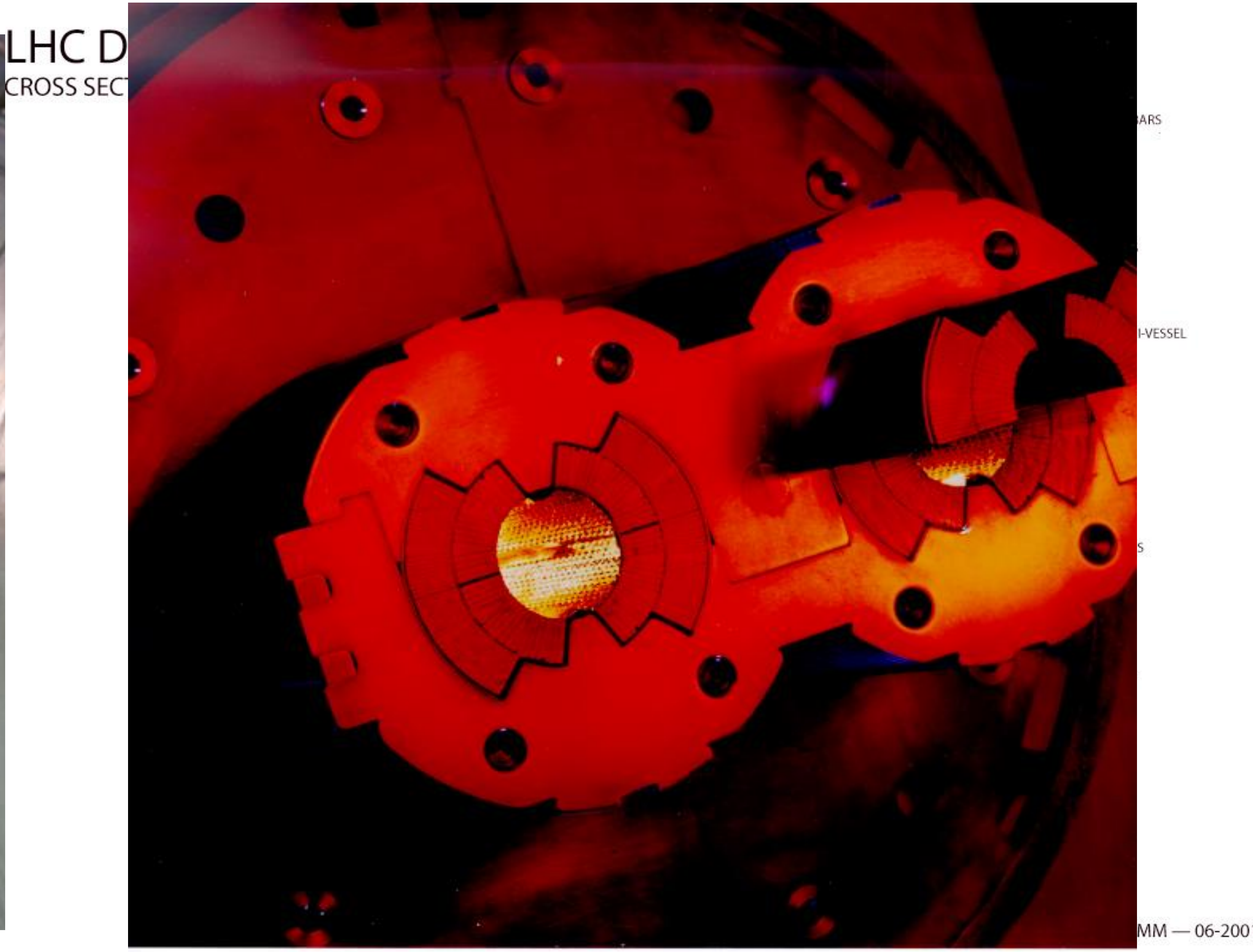
Accelerating cavities

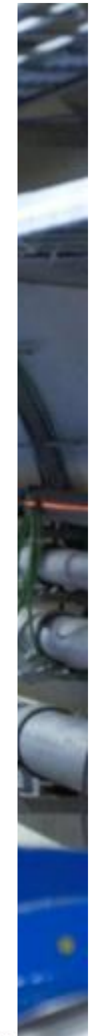




Magnets







The world's longest vacuum system (about 100Km):

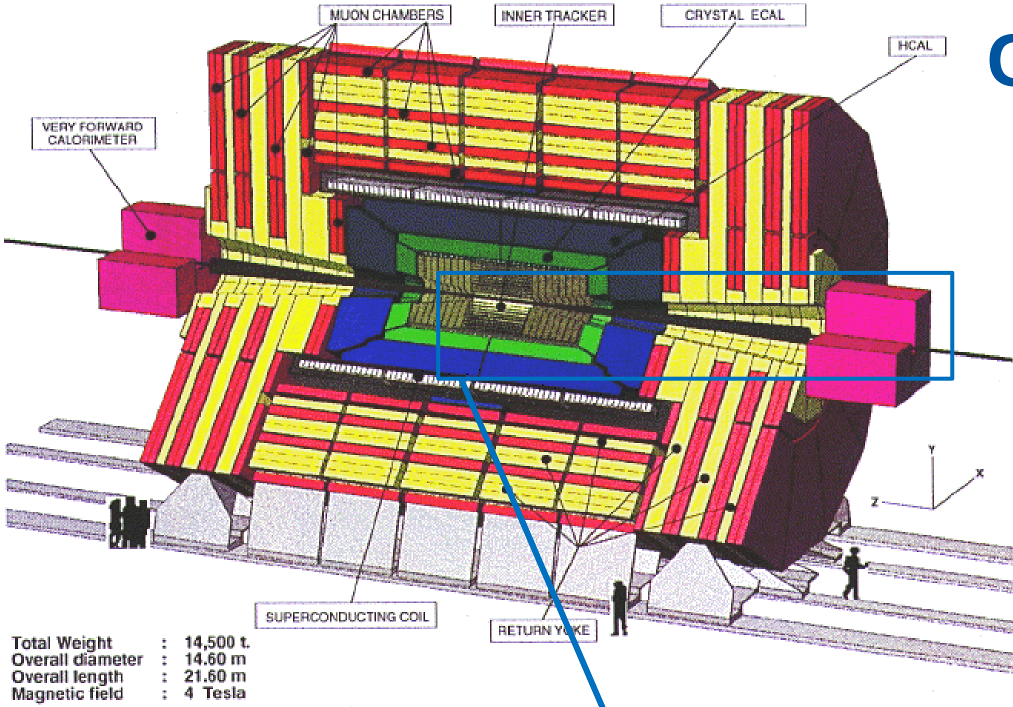
- pressure ranges from insulation vacuum (<10^{-3} mbar) to UHV in LHC (10^{-10} mbar) to XHV in LEIR (10-12 mbar)

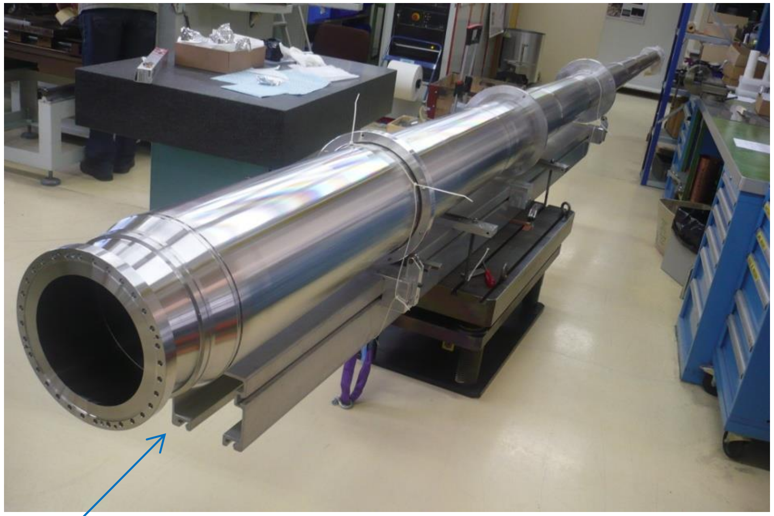
- necessary to reduce the beam/gas interaction (defocussing, energy spread, lifetime, noise in the detectors of the experiments)

- Pumping is achieved by mechanical pumps, Ion pumps, cryopumping and getters

Experimental vacuum system

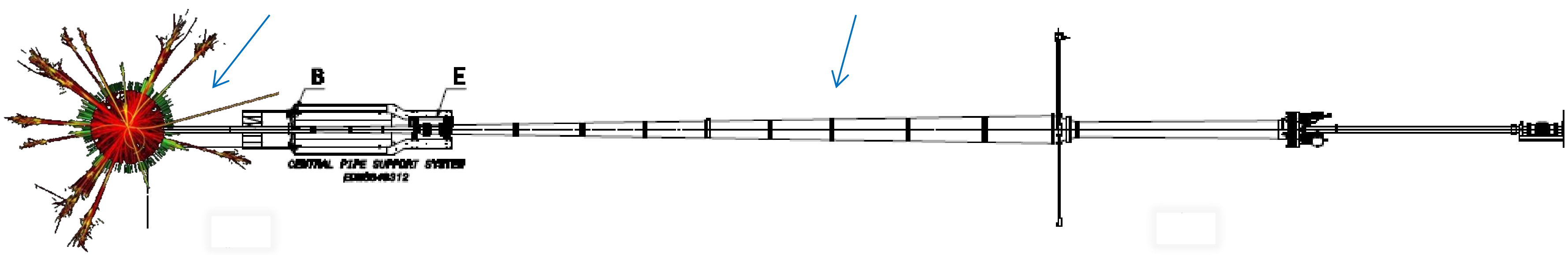
CMS





Central Pipe

Endcap Pipe



Particle detectors

Activities: Surfaces Chemistry and Coatings

Surface characterization and analysis (XPS, Auger, Secondary Electron Yield)

Chemical analysis (FTIR, UV-vis, Gas Chromatography, atomic absorption spectroscopy, DSC,….)

Surface modification by surface finishing (UHV grade cleaning, etching, electroplating, electrochemical characterization…)

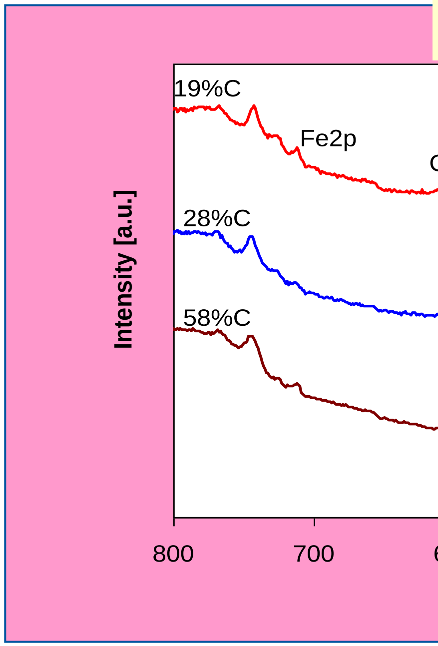
Thin film PVD coating (magnetron sputtering, evaporation)

The goal is to maintain/improve the performance of the accelerators and detectors in terms of availability, quality, lifetime of components: research and development

Monitoring cleanliness for UHV components:

FTIR
Through elution with C_6H_{14}

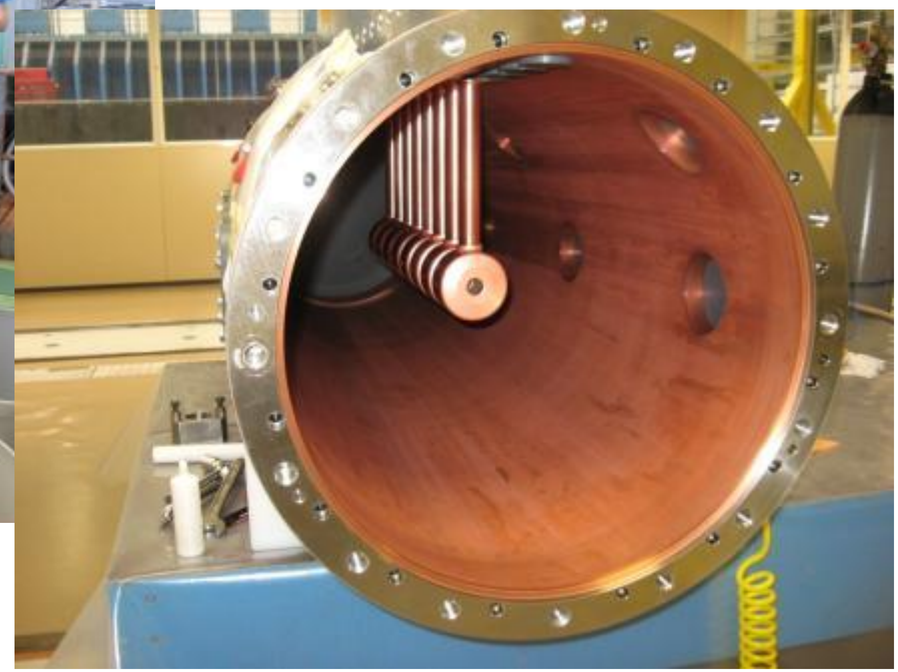
XPS



Copper plating of large objects (DTL tank)

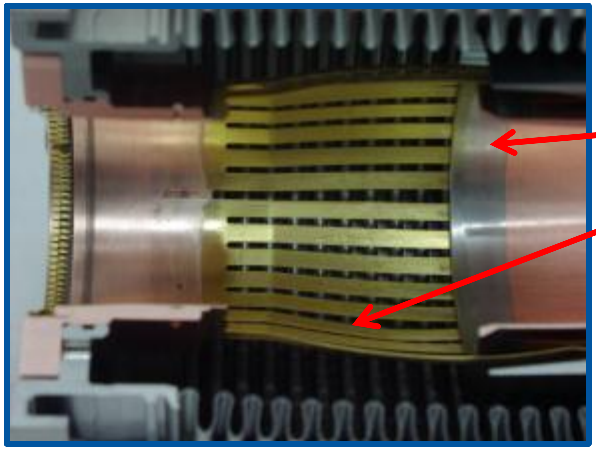
Difficult to obtain uniform plating
Small ratio bath-volume to surface

Final assembly with the electrodes for the accelerator



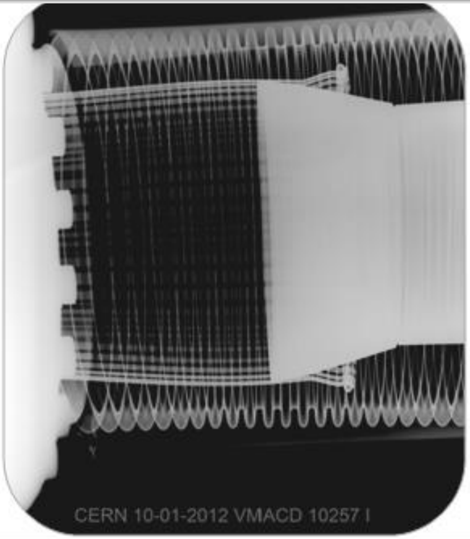
14

Plating of many different metals: Ag, Au, Rh on the LHC RF-contacts



Rh/Cu
Au/CuBe
Ag/CuBe

Radiography, installed

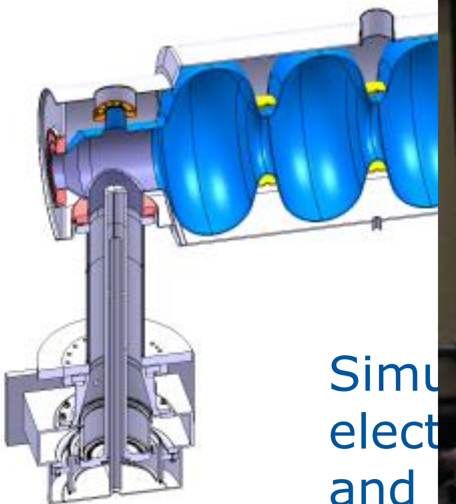


Inserted in the machine vacuum: cleanliness and purity to avoid degassing !

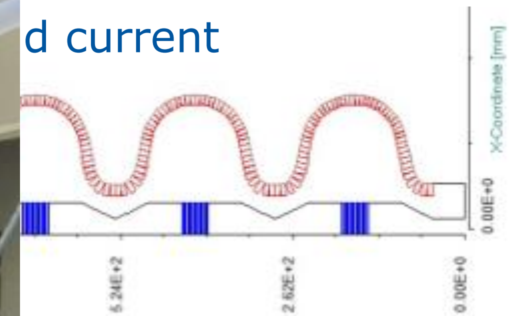
The Ag and Rh combination provides good electrical contact without cold-welding in vacuum

Optimization of current profile for the Electropolishing of Nb

5-cell cavi

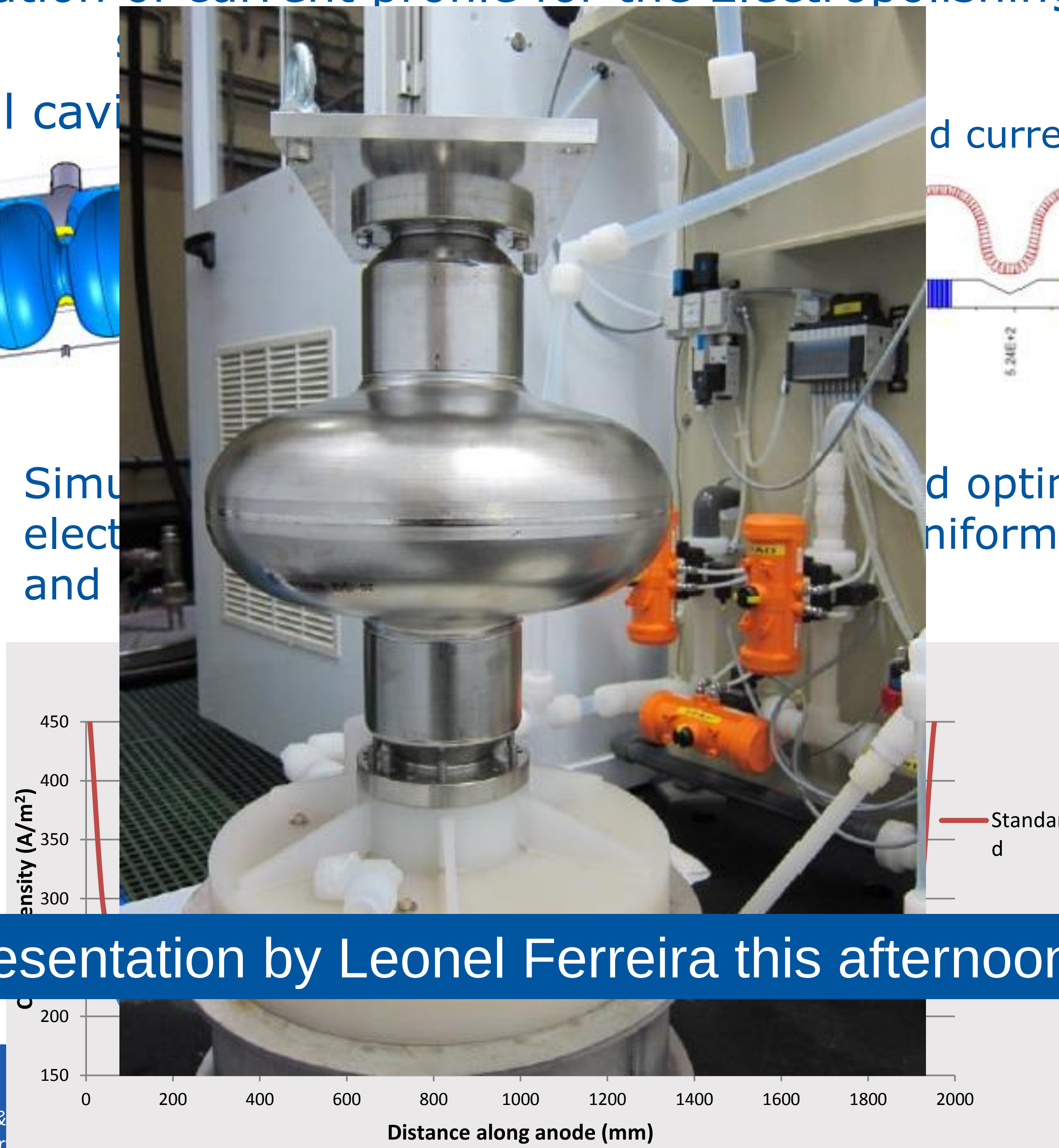


d current



Simu
elect
and

d optimized
niform current

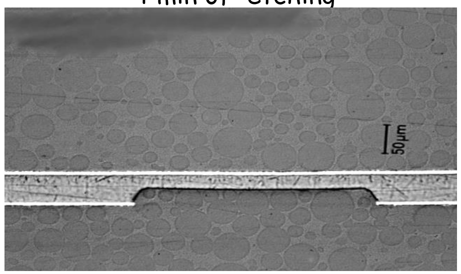


Presentation by Leonel Ferreira this afternoon

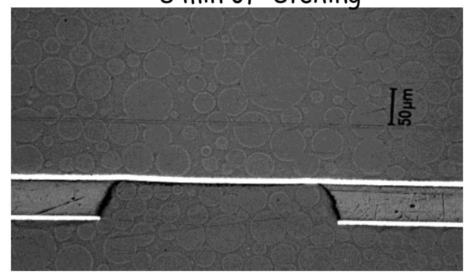
Anisotropic etching of polymides

Most interesting sample :
1 [5/50/5 um]

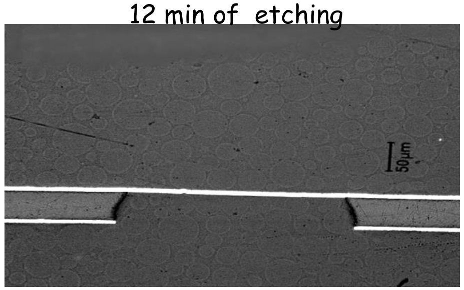
4 min of etching



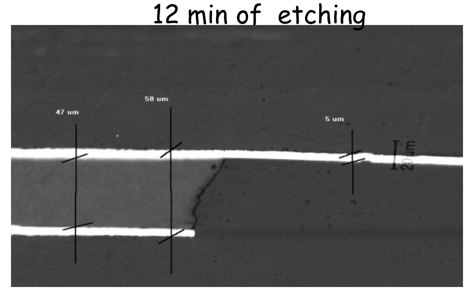
8 min of etching



12 min of etching



12 min of etching



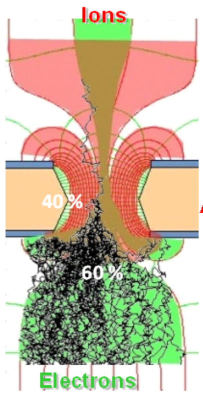
Highly anisotropic etching
Micron level definition
Wide process window

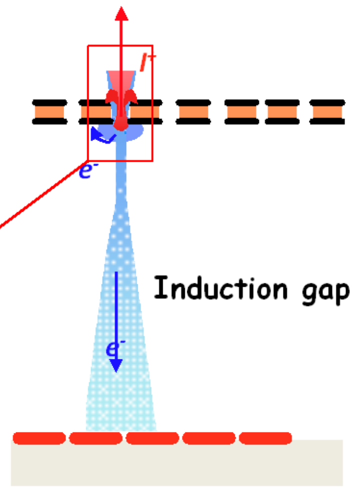
6

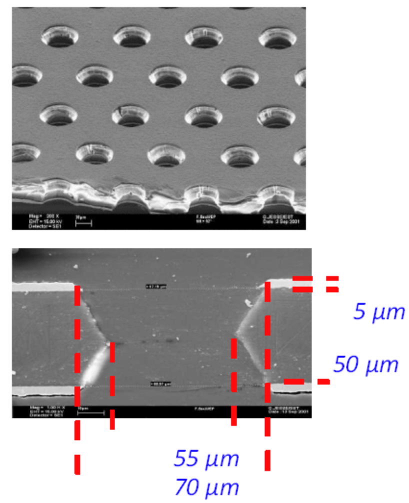
This process has already triggered four patents

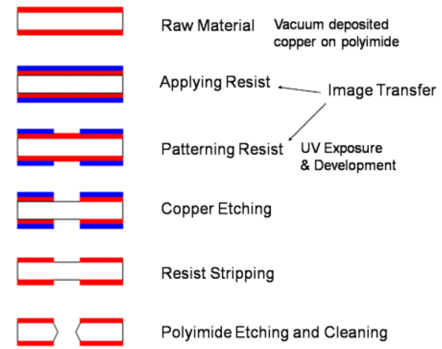
Advanced etching and lithographic techniques

GEM









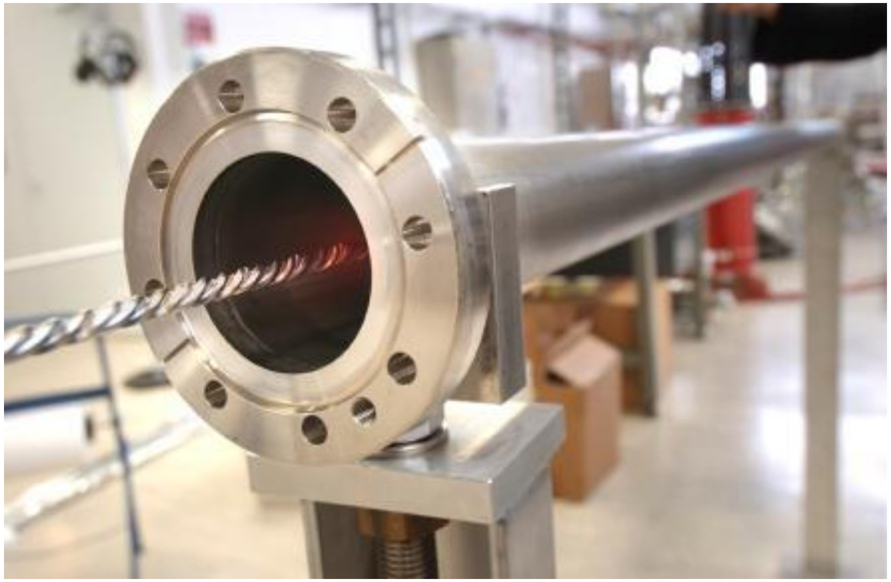
Thin, metal coated polyimide foil perforated with high density micron level accuracy holes pattern .

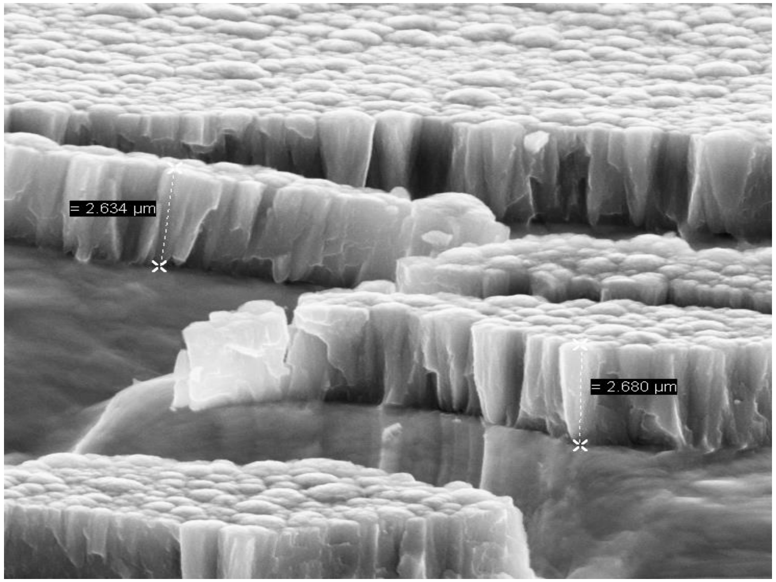
Electrons are collected on a patterned readout board.
A fast signal can be detected on the lower GEM electrode for triggering or energy discrimination.
All readout electrodes are at ground potential.

Presentation by Rui De Oliveira this afternoon

Coating of vacuum chambers

DC-magnetron sputtering with target made of intertwisted wires of Ti, Zr, V: developed at CERN in 1998. Patented and licensed to industry



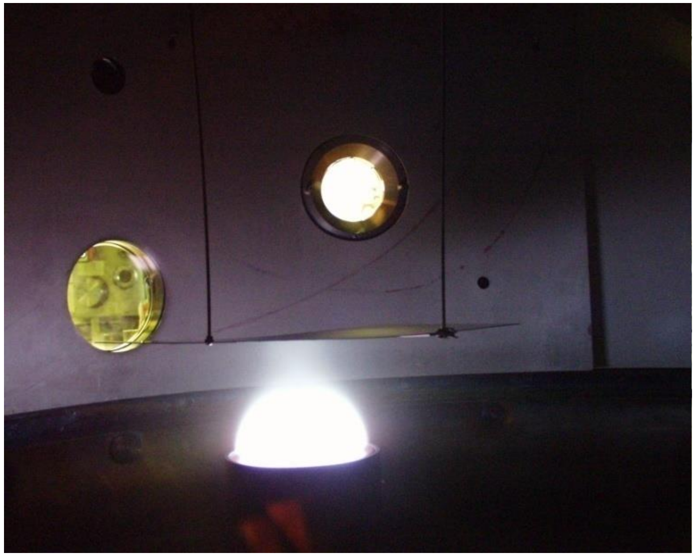


Activation temperature (~200 ºC) compatible with copper vacuum chambers (does not deteriorate too much the mechanical properties). Used for the LHC accelerator for pumping and low secondary yield (d_{max}=1.1 after activation) in 6 km of Long Straight Sections

Coating plant for LHC –LSS and detector chambers up to 7 m length

Presentation by Pedro Costa Pinto this afternoon

Lab size DC-magnetron sputtering facilities



Possibility to coat substrates up to 1.2 m length, substrate rotation for complex shapes

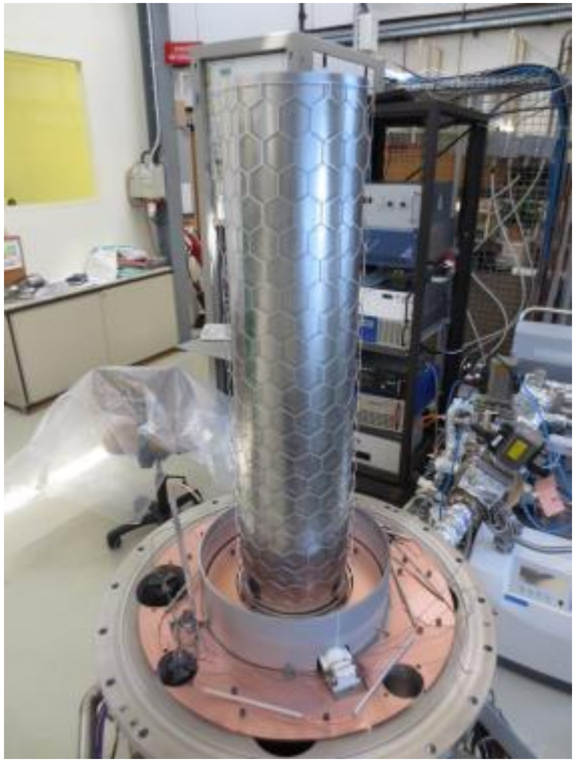
Up to 3 independent targets for alloy deposition with tunable composition

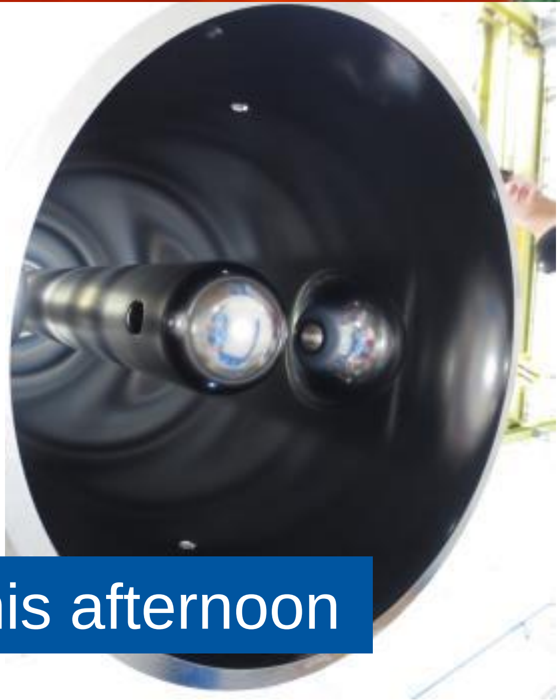
Typical materials:

- Cu, Au
- Ti
- NEG (TiZrV)
- Nb
- B_4C

Foreseen developments:
- insulators, reactive sputtering, RF magnetron…..

Nb/Cu cavities: HIE-ISOLDE

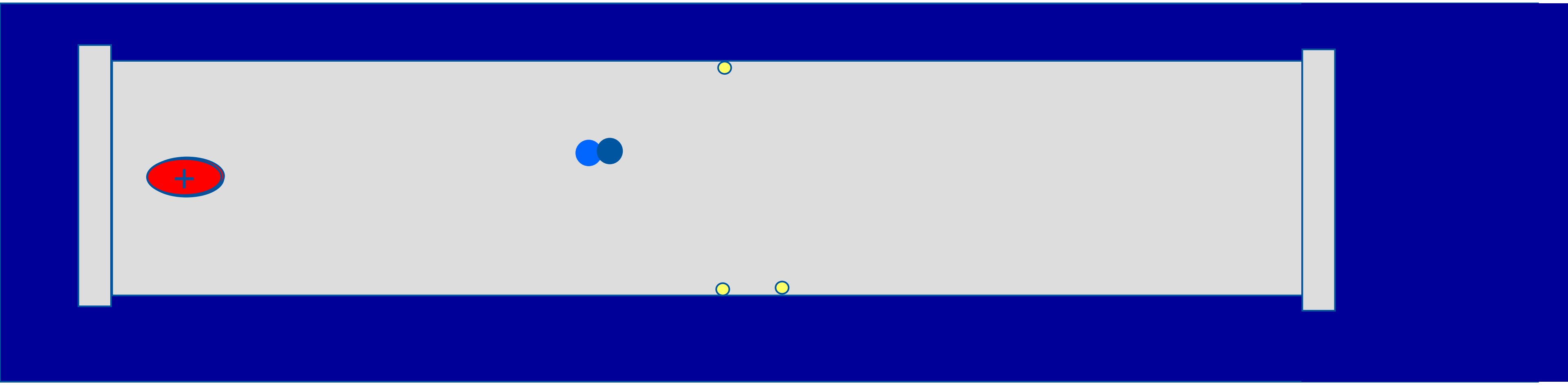




Substrate preparation (electropolishing or chemical polishing) are crucial for the success of the coating

Presentation by Wil Vollenberg this afternoon

Coatings preventing electron cloud



Proton bunch (charge +)

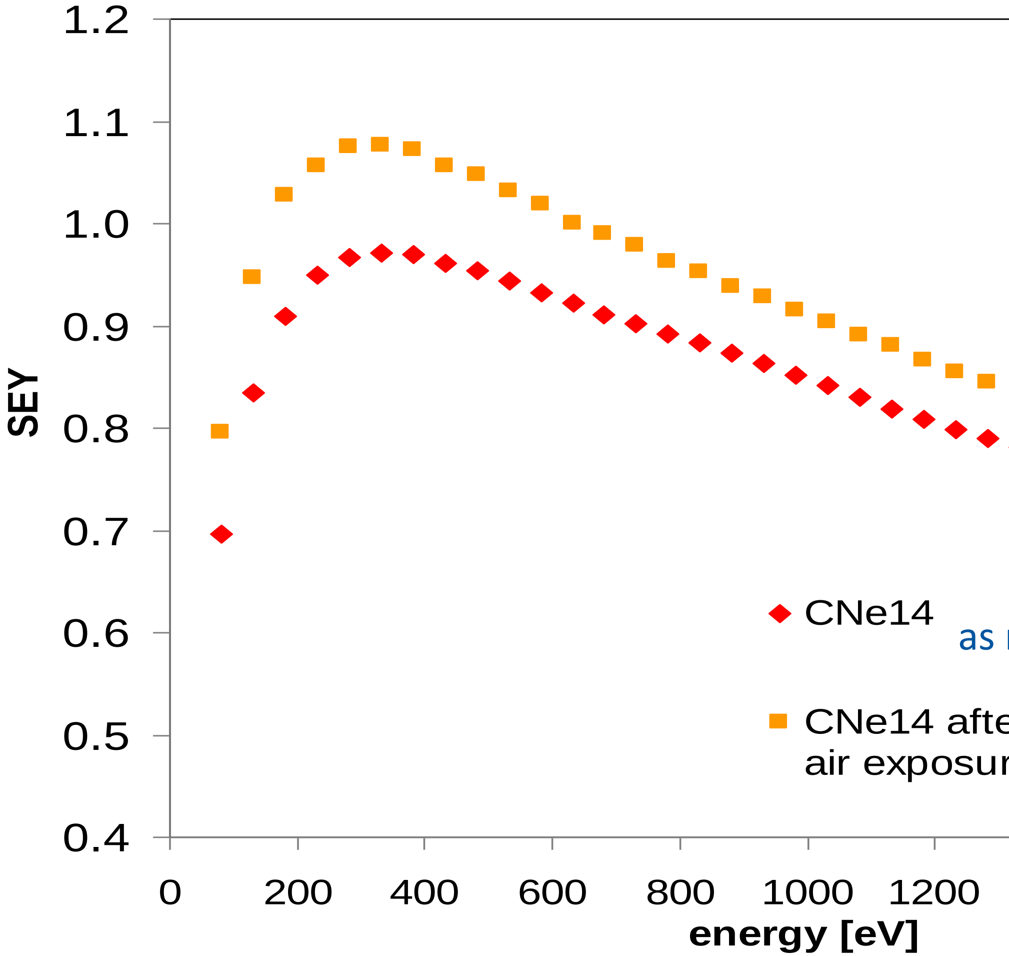
Gas molecule

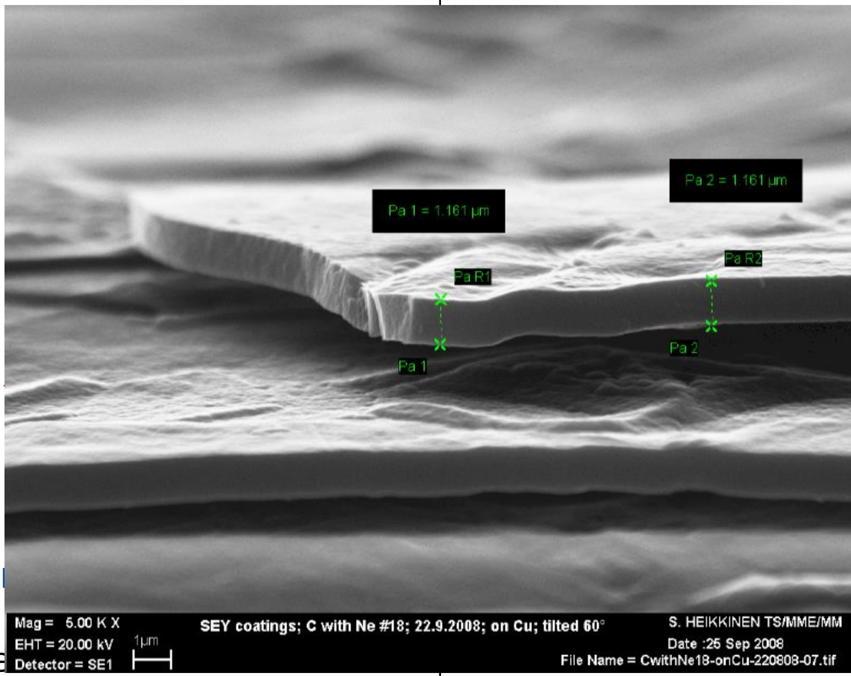
Electron (charge -)

The beam is perturbed by the electron multiplication; the problem is more important for high beam currents (beam potential) and short bunch spacing

To reduce the effect one must reduce the secondary electron yield of the walls or attract the generated electrons by other means

The possible solution : carbon a-C coatings





as

Dose below 10^{-6} Clb/mm^2

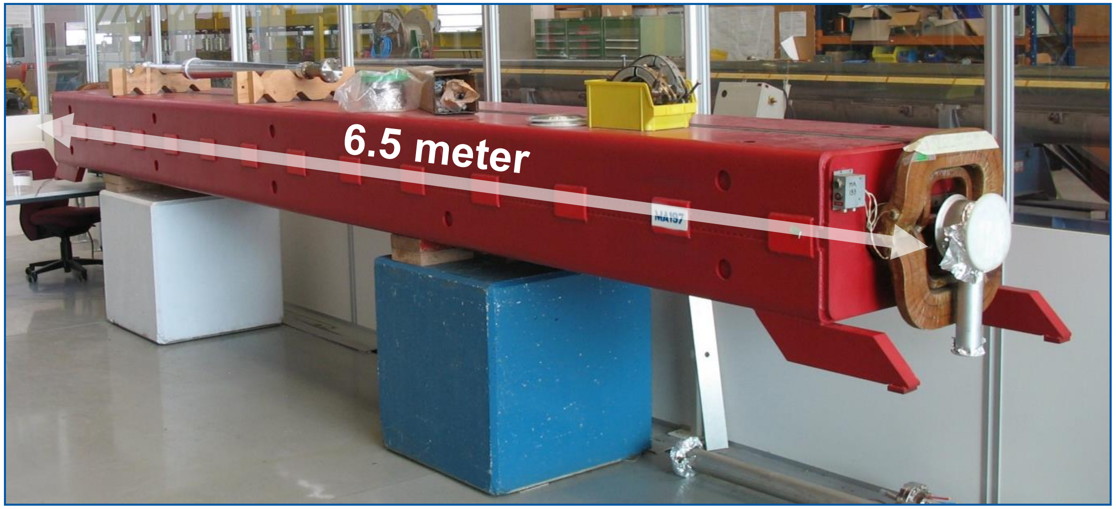
-a-C coating on copper deposited by magnetron sputtering (in Ne)
-as expe
-development started in 2008

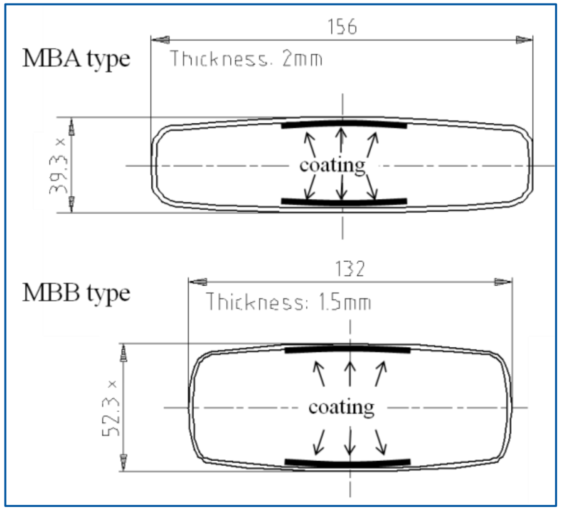
More on this topic by Mounir Mensi this afternoon

Introduction: SPS dipoles

Almost 5 km of the SPS are filled with MBB and MBA type dipoles (>700).

The length of each dipole is 6.5 m and weights ~18 tons.





The beampipes are embedded in the yoke.

coat new beampipes, open the dipole, exchange beampipe, close the dipole.

Easy to coat

Too expensive (open/close dipole)

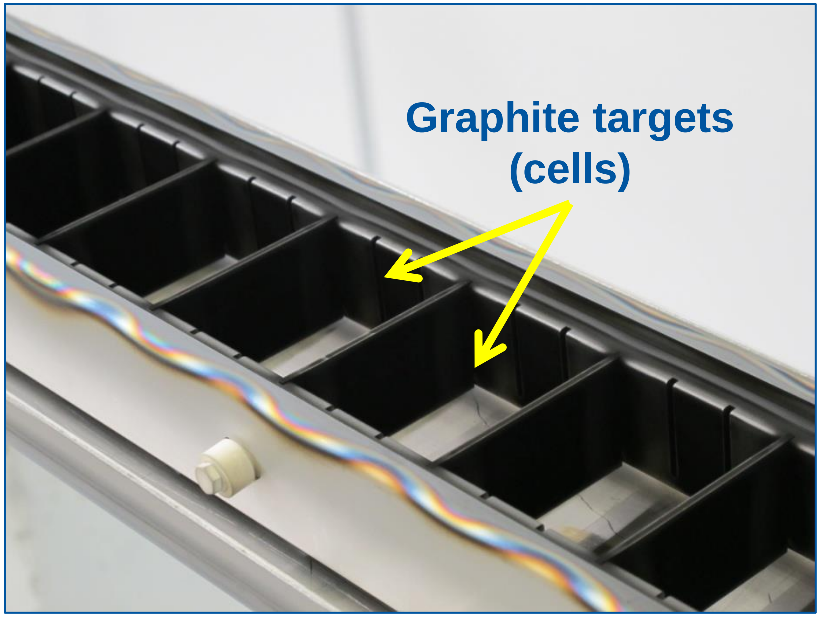
coat the actual beampipes directly in the dipole.

Easy to coat

cheaper

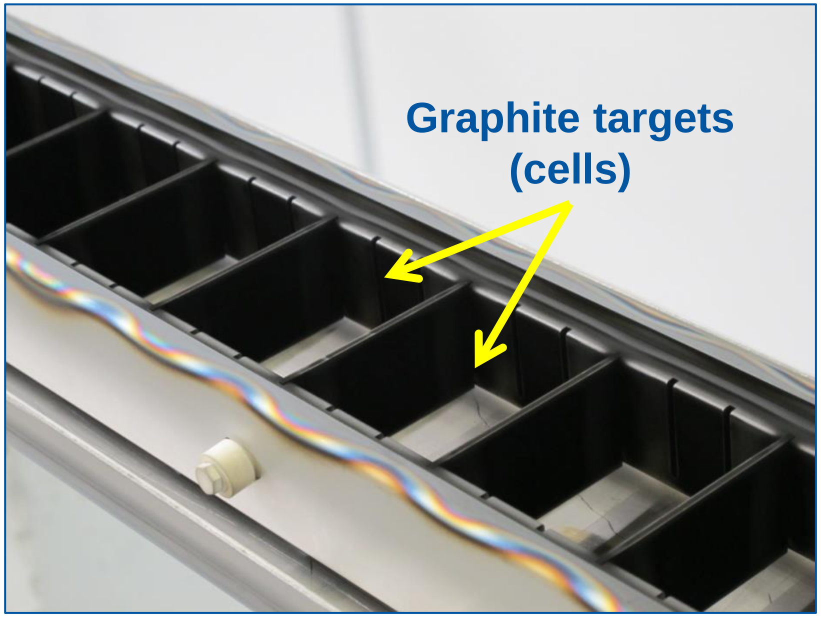
DC hollow cathode

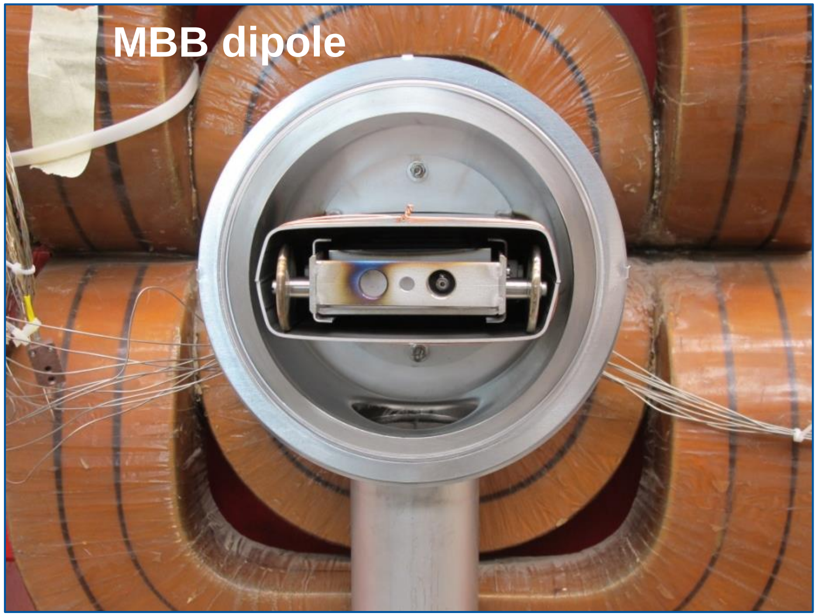
Coat actual beampipes by DC Hollow Cathode Sputtering (DCHCS)



DC hollow cathode

Coat actual beampipes by DC Hollow Cathode Sputtering (DCHCS)

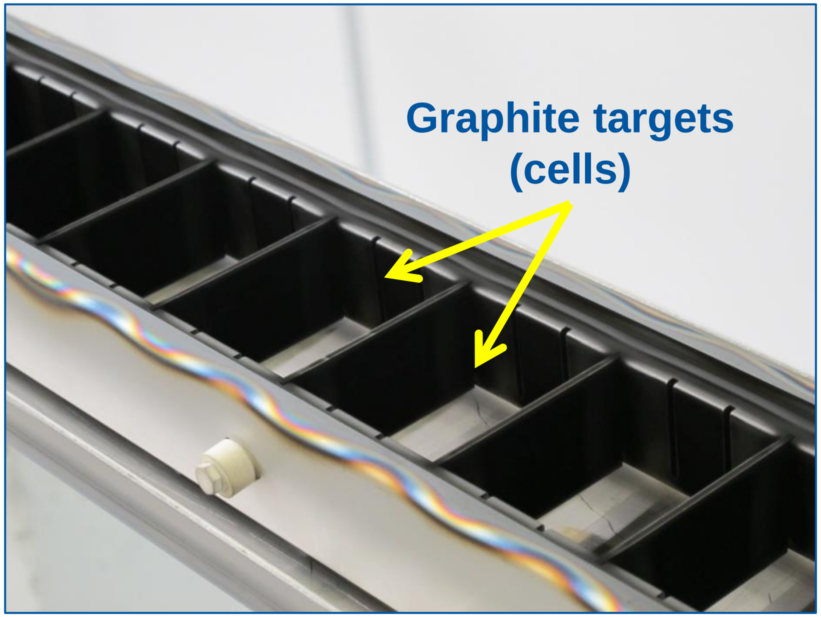


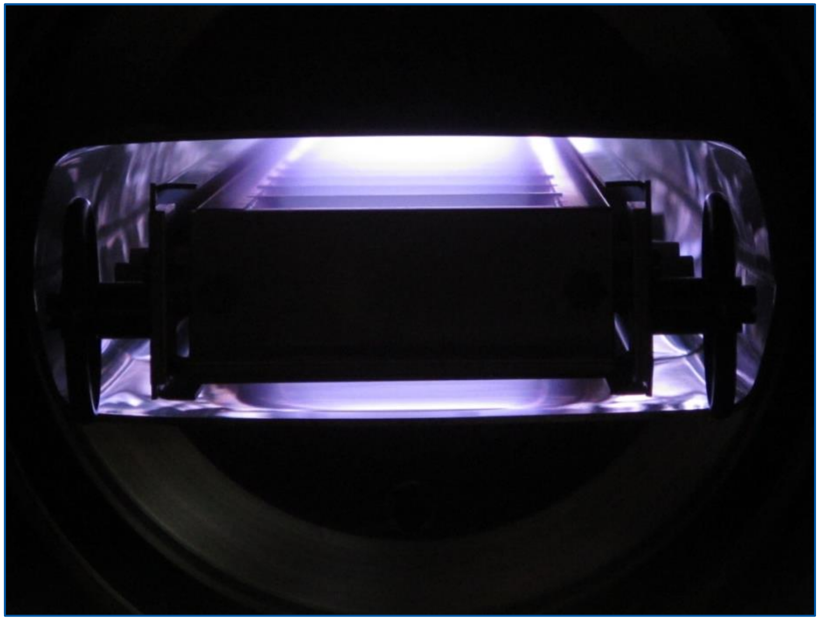


DC hollow cathode

Coat actual beampipes by DC Hollow Cathode Sputtering (DCHCS)

THE TECHNIQUE IS MATURE FOR LARGE SCALE PRODUCTION





Pressure: 1.1 x10^{-1} mbar (Ar)
Power: 0.9 kW (1.5A @ 600 V)
0.5 μm in 20 hours

Research interests

- Treatments or coatings to lower the SEY of insulator surfaces, like alumina, and metals
- NEGs with lower activation temperature than TiZrV
- Simulations of electron-ion plasma for coating systems
- Methods to produce thin films of refractory metals in small diameter tubes (< 10 mm), as electrochemical means…
- HIPIMS on SC RF cavities and more….
- Structured films
- Coatings as permeation barriers for high transparency vacuum chambers
- flexible (!) insulating coatings
- Coating/treating of long (30m) accelerator vacuum systems without dismounting the beamline
- Novel cleaning techniques for UHV applications
- Simulation of electrochemical processes in complex geometries